Thermal analysis of a 3× Pylontech US3000C energy storage system using a lumped R-C model and PSIM implementation

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***Abstract*—This article presents a thermal model of an energy storage system consisting of three Pylontech US3000C modules connected in parallel on a 48 V DC bus. R-C model was used, in which the heat source is Joule losses resulting from the internal resistance of the cells and the operating current. During analyze two environmental extremes are considered: -30°C and 45°C. The model shows that normal daily cycling generates only a few watts of heat at 35 A and approximately 14 W at 75 A for the whole stack. Consequently, self-heating is insufficient in winter. Therefore, the operational limitation is not overheating, but the risk of charging LiFePO4 cells at subzero temperatures, associated with the possibility of lithium plating. For the summer condition of 45°C, the maximum model temperature remains below the BMS thresholds of 55°C for charging and 60°C for discharging, with the assumed daily load profile. The article also includes a procedure for implementing the model in the PSIM environment as an electrothermal analogy and recommendations for heating, ventilation and measurement validation.**

Keywords—***LiFePO4, natural convection, Pylontech US3000C, energy storage, R-C thermal model, Joule losses, lithium plating, BMS, PSIM***

I. Introduction

Energy storage systems (ESS) based on modular LiFePO4 batteries are widely used in off-grid and hybrid photovoltaic installations due to the technology's high chemical safety and the ease of expansion by paralleling modules on a common DC bus. A typical example is the Pylontech US3000C module—a self-balancing pack of 15 LiFePO4 cells connected in series (15S), with a nominal voltage of 48 V, equipped with its own BMS.

However, the operation of lithium iron phosphate cells is strongly dependent on temperature. The manufacturer limits the module's operating range to 0-50°C during charging and -10-50°C during discharging, with the optimal range stated as 10-40°C. The purpose of this study is to assess whether, under extreme conditions (Arctic frost -30°C and heat 45°C), the internal thermal losses of a 3× US3000C array can significantly change the cell temperature, and to identify the actual operational limitations of such an array.

Lumped-parameter R-C thermal model was used for the analysis, in which the battery module is represented as a single thermal node with a capacity C_th, exchanging heat with the environment through a thermal resistance R_th, and powered by a heat source corresponding to the Joule losses. Despite its simplifications, this model is widely used in the preliminary design of battery thermal management systems (BTMS) and produces results consistent with distributed models (FEM/CFD) at a significantly lower computational cost, as confirmed by recent work on the parameterization of lumped pouch and cylindrical cell models.

II. Characteristics of the Test Object

The analyzed energy storage system consists of three identical Pylontech US3000C modules connected in parallel on a common 48 V DC bus (3P configuration, each module internally 15S). The table below summarizes the catalog parameters of a single module, used as input data for the model.

Tab. 1 Catalog parameters of the Pylontech US3000C module (data from the manufacturer's operating instructions, version 1.1).

Parameter	Value	Notes
Nominal voltage	48 V	15 LiFePO4 cells in series (15S)
Nominal capacity	3552 Wh	≈74 Ah at 48 V
Usable capacity	3374,4 Wh	DoD 95%
Dimensions	442 × 420 × 132 mm	19" housing
Weight	32 kg	Single module
Discharge voltage	44,5 - 53,5 V	
Charging voltage	52,5 - 53,5 V	
Recommended current (charge/discharge)	37 A	Continuous work cycle
Maximum current	74 A	